Pulse Instruments

PUL

PULSE INSTRUMENTS COMPANY
USER'S REFERENCE MANUAL
MODEL PI-720
±25V PROGRAMMABLE DUAL BIPOLAR
DC SOURCE WITH 4½ DIGIT DISPLAY

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±25V PROGRAMMABLE DUAL BIPOLAR

DC SOURCE WITH 4½ DIGIT DISPLAY

PRELIMINARY

Pulse Inst.
213-515-5330

SIZE	CODE IDENT NO.	DRAWING NO. 91000150
SCALE		SHEET 1 of 8

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I. GENERAL DESCRIPTION

The PI-720 Programmable Dual Bipolar DC Source is a plug-in unit designed to operate in the Tektronix TM-500 series power modules. Each channel employs a precision 4½ digit monolithic A/D converter for measuring the output voltage or load current. A 4½ digit LED display unit is also provided for each channel. Minimum display resolution is 0.1mV or 0.1μA, and Auto Ranging is provided in the Digital Programming Mode (Option 002). The PI-720 is a Talker/Listener type instrument.** In the Listen mode, its output voltage, voltage or current display, and display range can be programmed. Programming resolution is 12mV for dual channel operation and 1mV or 0.5mV when both channels are combined. In the Talk mode, it reports back to the controller the measured results.

With the additional DVM inputs, the PI-720 can be used as system DVM's for measuring and recording other DC voltages. The PI-720 DC Source employs operational amplifier type output stages. Consequently, the output voltage of each channel can be varied continuously from positive values, through zero, to negative values. Furthermore, each output can source or sink a maximum of 150mA regardless of the output voltage polarity or value. Output voltage of each channel is manual-adjustable or digitally programmable within the ±25V range and is short circuit protected. The PI-720 can, therefore, be used as a dual channel DC measurement system.

**For use with IEEE-488 (GPIB) Bus, the TM/RTM 506-MOD DP power module and the PI-952 Bidirectional Instrument Coupler are required.

II. SPECIFICATIONS

1. FORCE FUNCTION

Output Voltage Range

±25V DC, manual control or external programming selectable by front panel switch; I_O = ±150mA maximum for $-25 \leq V_O \leq +25V$.

Manual - Continuously variable from -25V to +25V by front panel control.

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2. SENSE FUNCTION

Range	Max. Reading	Accuracy (18° - 28° c)	
		Volts	MA
2	1.9999	0.1% rdg ±0.3mV	0.2% rdg ±0.8μA
20	19.999	0.1% rdg ±3mV	0.2% rdg ±8μA
200	199.99	0.1% rdg ±30mV	0.25% rdg ±80μA

DVM INPUT

1 MΩ, ±100V Maximum

Measurement Cycle Time

336ms typical

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III FRONT PANEL CONTROLS

1. Channel A display, volts or milliamps.
2. Channel A DVM Input - to be used for measuring external voltages, ±100V, max.
3. Channel A Output - ±25V, ±150mA, maximum.
4. Channel A Output manual control, coarse.
5. Channel A Output manual control, fine.
6. Channel A manual function selector switch.
7. Channel A manual display range selector switch.
8. Channel B display, volts or milliamps.
9. Channel B DVM Input - to be used for measuring external voltages, ±100V, max.
10. Channel B Output - ±25V, ±150mA, maximum.
11. Channel B Output manual control, coarse.
12. Channel B Output manual control, fine.
13. Channel B manual function selector switch.
14. Channel B manual display range selector switch.
15. Mode selector switch-

    OFF: Power supply in standby mode. Outputs are within ±25mV.

    MANUAL: Output controlled by front panel coarse/fine potentiometer control.

    DIGITAL PROGRAMMING: All front panel controls and selector switches are disabled. Output voltages, display ranges and function selections are controlled by host computer. See 'Digital Programming for PI-Series Plug-In Instruments.'

16. Digital Programming Status indicator:

    REM: Remote mode, indicating PI-720 is in digital programming mode.

    LSN: Listen mode, indicating that the PI-720 is receiving information.

    TLK: Talk mode, indicating that the PI-720 is outputting information.

    HR: High Resolution, indicating Channel A and Channel B are combined to produce a high resolution output at Channel A providing either a 1mV or .5mV programming resolution.

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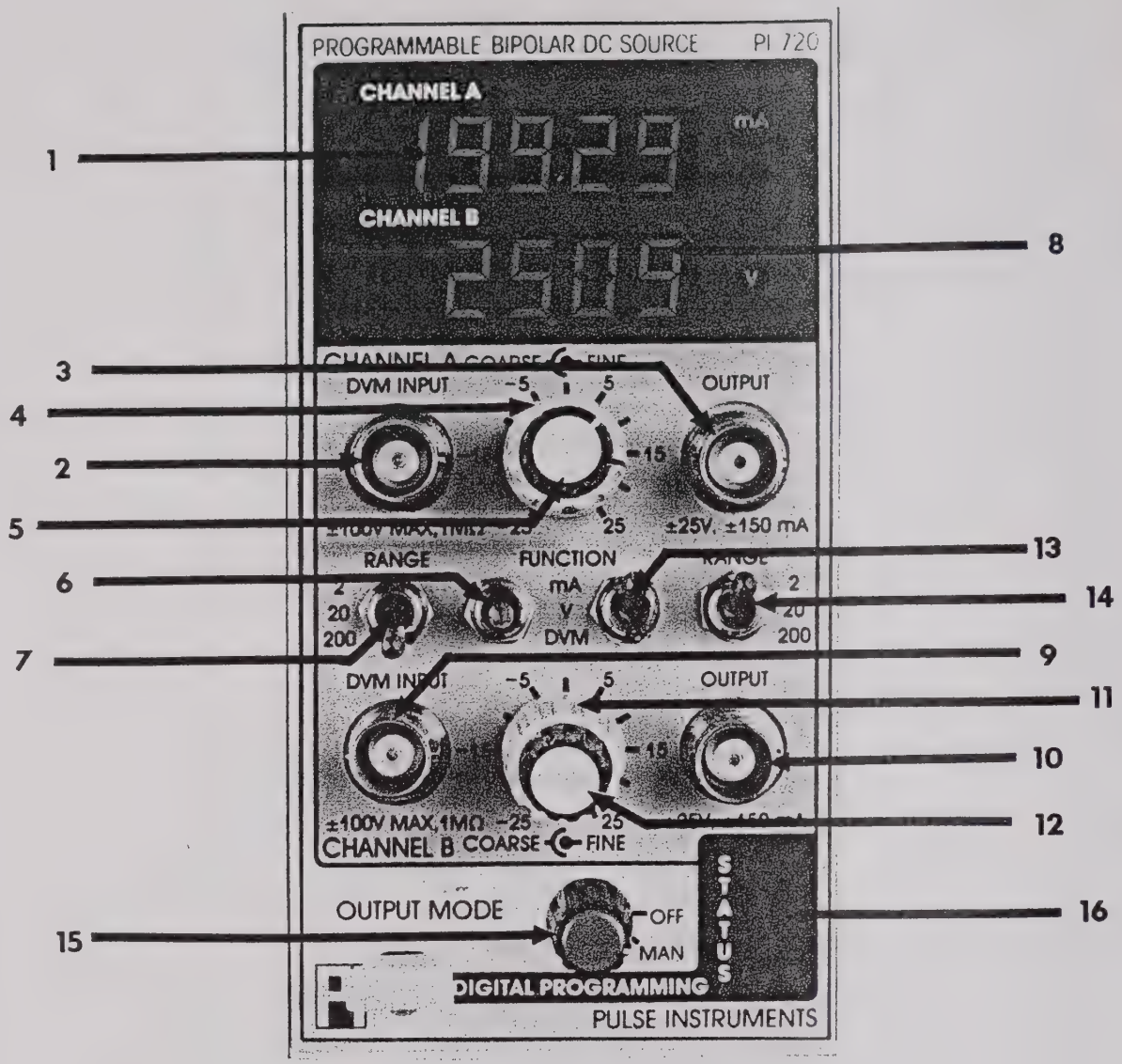

SIZE	CODE IDENT NO.	DRAWING NO.
		91000150
SCALE		SHEET 6 of 8

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IV. PROGRAMMING COMMANDS

80 Resets both channels to:

- 0.00V
- Auto ranging on
- High resolution off/12mv increments
- DVM's off

90 Execute command used to terminate input

81 Sets channel A auto ranging on

91 Sets channel B auto ranging on

82 Sets channel A auto ranging off

92 Sets channel B auto ranging off

83 Sets channel A to read internal power supply voltage

93 Sets channel B to read internal power supply voltage

84 Sets channel A to read power supply current

94 Sets channel B to read power supply current

85 Sets 2 range on Channel A

95 Sets 2 range on channel B

86 Sets 20 range on channel A

96 Sets 20 range on channel B

87 Sets 200 range on channel A

97 Sets 200 range on channel B

88 Sets channel A DVM to read external voltage

98 Sets channel B DVM to read external voltage

89 Sets channel A external DVM off

99 Sets channel B external DVM off

8A Sets high resolution on (channel A + channel B)

9A Sets high resolution off

8B Sets resolution to 1 mv.

9B Sets resolution to .5mv

8C Takes a reading from channel A

9C Takes a reading from channel B

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Except for 80, 90, 8A, 9A, 8B and 9B, commands beginning with the digit '8', such as 81 and 8C, control channel A functions, and those with the digit '9', control channel B functions. For example, an '8C' stores the channel A displayed information in memory which can be read by the controller at a later time; only one reading may be stored in memory at a given time. However, if the command '8C' is not used, and if channel A is selected for TALK, the instantaneous displayed information will be sent to the controller.

All commands must have a '90' at the end of the command string; otherwise, the instrument will not respond to the command string. Example: 84 82 86 07 1? 2? 90.

The command string sets channel A to: current, auto range off, 20 ma range, then loads a voltage of 12.5 volts.

SIZE	CODE IDENT NO.	DRAWING NO. 91000150
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```
U=1:CH=1
PRINT CLR$
PRINT HI$;HOME$:PRINT TAB(25);"720"
PRINT
IF CH=1 THEN CHN=1 ELSE CHN=2
PRINT TAB(5);HI$;"M";LI$;"ODE ";CLRL$;HI$;
IF M(PL(U),CHN)=0 THEN PRINT "VOLTS"
IF M(PL(U),CHN)=1 THEN PRINT "CURRENT"
PRINT TAB(5);"D";LI$;"VM ";CLRL$;HI$;:IF D(PL(U),CHN)=0 THEN PRINT "OFF"
IF D(PL(U),CHN)=1 THEN PRINT "ON"
PRINT TAB(5);"H";LI$;"IGH RESOLUTION ";CLRL$;HI$;
IF H(PL(U))=0 THEN PRINT "OFF"
IF H(PL(U))=1 THEN PRINT "ON"
PRINT TAB(5);"I";LI$;"NCREMENT ";CLRL$;HI$;
IF I(PL(U))=0 THEN PRINT "1 MV"
IF I(PL(U))=1 THEN PRINT ".5 MV"
PRINT TAB(5);LI$;"RANGE ";CLRL$;HI$;"U";LI$;"P DO"HI$;"W";LI$;"N ";HI$;
IF R(PL(U),CHN)=0 THEN PRINT "AUTO"
IF R(PL(U),CHN)=1 THEN PRINT "2"
IF R(PL(U),CHN)=2 THEN PRINT "20"
IF R(PL(U),CHN)=3 THEN PRINT "200"
PRINT TAB(5);LI$;"PROGRAMED VOLTAGE ";HI$;CLRL$;VOLT$(PL(U),CHN)
PRINT:PRINT TAB(18);"READINGS":PRINT
PRINT TAB(5);LI$;"V";HI$;"O";LI$;"LTS";HI$;TAB(25);"C";LI$;"URRENT";
PRINT TAB(45);LI$"D";HI$;"V";LI$;"M";HI$
PRINT
PRINT CLRL$;
PRINT TAB(5);MID$(V1$(PL(U),CHN),2,7);TAB(20);MID$(I1$(PL(U),CHN),2,7);
PRINT TAB(39);MID$(D1$(PL(U),CHN),2,7)
PRINT
PRINT "------------------------------------------------------"
PRINT TAB(15);LI$;"SLOT ";HI$;PL(U);TAB(25);LI$;"CHANNEL ";
PRINT HI$;:IF CH=1 THEN PRINT "A"
IF CH=6 THEN PRINT "B"
DIS$="B1"+CHR$(PL(U)+48)+CHR$(CH+48)
A$=INKEY$:IF A$="" THEN 1800
IF A$<>"M" THEN 1910
IF D(PL(U),CHN)=1 THEN 1800
IF M(PL(U),CHN)=1 THEN M(PL(U),CHN)=0 ELSE M(PL(U),CHN)=1
IF M(PL(U),CHN)=0 AND CHN=1 THEN CODE$="83"
IF M(PL(U),CHN)=1 AND CHN=1 THEN CODE$="84"
IF M(PL(U),CHN)=0 AND CHN=2 THEN CODE$="93"
IF M(PL(U),CHN)=1 AND CHN=2 THEN CODE$="94"
GOSUB 5970
CODE$=CODE$+"90":GOSUB 5820
GOTO 1470
IF A$<>"D" THEN 2010
IF D(PL(U),CHN)=1 THEN D(PL(U),CHN)=0 ELSE D(PL(U),CHN)=1
IF D(PL(U),CHN)=1 THEN M(PL(U),CHN)=0
IF D(PL(U),CHN)=1 AND CHN=1 THEN CODE$="8890"
IF D(PL(U),CHN)=1 AND CHN=2 THEN CODE$="9890"
IF D(PL(U),CHN)=0 AND CHN=1 THEN CODE$="8990"
IF D(PL(U),CHN)=0 AND CHN=2 THEN CODE$="9990"
GOSUB 5970
GOSUB 5820
GOTO 1470
IF A$<>"H" THEN 2080
IF H(PL(U))=1 THEN H(PL(U))=0 ELSE H(PL(U))=1
IF H(PL(U))=0 THEN CODE$="9A90"
IF H(PL(U))=1 THEN CODE$="8A90"
GOSUB 5970
```

```
60 GOSUB 5820
70 GOTO 1470
80 IF A$<>"I" THEN 2150
90 IF I(PL(U))=1 THEN I(PL(U))=0 ELSE I(PL(U))=1
00 IF I(PL(U))=0 THEN CODE$="8B90"
10 IF I(PL(U))=1 THEN CODE$="9B90"
20 GOSUB 5970
30 GOSUB 5820
40 GOTO 1470
50 IF A$<>"U" THEN 2280
60 R(PL(U),CHN)=R(PL(U),CHN)+1:IF R(PL(U),CHN)>3 THEN R(PL(U),CHN)=3
70 IF R(PL(U),CHN)=0 AND CHN=1 THEN CODE$="8190"
80 IF R(PL(U),CHN)=1 AND CHN=1 THEN CODE$="828590"
90 IF R(PL(U),CHN)=2 AND CHN=1 THEN CODE$="828690"
00 IF R(PL(U),CHN)=3 AND CHN=1 THEN CODE$="828790"
10 IF R(PL(U),CHN)=0 AND CHN=2 THEN CODE$="9190"
20 IF R(PL(U),CHN)=1 AND CHN=2 THEN CODE$="929590"
30 IF R(PL(U),CHN)=2 AND CHN=2 THEN CODE$="929690"
40 IF R(PL(U),CHN)=3 AND CHN=2 THEN CODE$="929790"
50 GOSUB 5970
60 GOSUB 5820
70 GOTO 1470
80 IF A$<>"W" THEN 2310
90 R(PL(U),CHN)=R(PL(U),CHN)-1:IF R(PL(U),CHN)<0 THEN R(PL(U),CHN)=0
00 GOTO 2170
10 IF A$<>CHR$(8) THEN 2340
20 IF CH=6 THEN CH=1
30 GOTO 1470
40 IF A$<>CHR$(12) THEN 2370
50 IF CH=1 THEN CH=6
60 GOTO 1470
70 IF A$<>CHR$(10) THEN 2400
80 U=U+1:IF U>B THEN U=B
90 GOTO 1470
00 IF A$<>CHR$(11) THEN 2430
10 U=U-1:IF U<1 THEN U=1
20 GOTO 1470
30 IF A$<>"-" THEN 2460
40 IF V$<>"" THEN 1800
50 V$=A$:PRINT CLRL$;V$;:GOTO 1800
60 IF A$<>"." THEN 2490
70 IF V=1 THEN 1800
80 V$=V$+A$:V=1:PRINT CR$;CLRL$;V$;:GOTO 1800
90 IF ASC(A$)<&H30 OR ASC(A$)>&H39 THEN 2510
00 V$=V$+A$:PRINT CR$;CLRL$;V$;:GOTO 1800
10 IF A$<>CHR$(13) THEN 2560
20 IF VAL(V$)>MAX OR VAL(V$)<MIN THEN 2550
30 VOLT$(PL(U),CHN)=V$:PRINT CR$;CLRL$;V$;:V$="":V=0
40 PRINT CR$;CLRL$:GOTO 3040
50 V=0:V$="":PRINT CR$;CLRL$;:GOTO 1800
60 IF A$<>"X" THEN 2580
70 GOTO 520
80 IF A$<>"O" THEN 2740
90 IF CHN=2 THEN 2670
00 CODE$="898390":GOSUB 5970:GOSUB 5820
10 FOR TIME=1 TO DELAY:NEXT TIME:GOSUB 6290
20 CODE$="":IF D(PL(U),1)=1 THEN CODE$=CODE$+"8890"
30 IF M(PL(U),1)=1 THEN CODE$=CODE$+"898490"
40 IF M(PL(U),1)=0 THEN CODE$=CODE$+"8390"
50 V1$(PL(U),1)=VIN$
60 GOSUB 5820:GOTO 1470
```

```
570 CODE$="999390":GOSUB 5970:GOSUB 5820
580 FOR TIME=1 TO DELAY:NEXT TIME:GOSUB 6290
690 CODE$="":IF D(PL(U),2)=1 THEN CODE$=CODE$+"9890"
700 IF M(PL(U),2)=1 THEN CODE$=CODE$+"999490"
710 IF M(PL(U),2)=0 THEN CODE$=CODE$+"9390"
720 V1$(PL(U),2)=VIN$
730 GOSUB 5820:GOTO 1470
740 IF A$<>"C" THEN 2890
750 IF CHN=2 THEN 2820
760 GOSUB 5970
770 CODE$="898490":GOSUB 5820:FOR TIME=1 TO DELAY:NEXT TIME:GOSUB 6290
780 I1$(PL(U),1)=VIN$
790 CODE$="":IF D(PL(U),1)=1 THEN CODE$=CODE$+"8890"
800 IF M(PL(U),1)=0 THEN CODE$=CODE$+"8390"
810 GOSUB 5820:GOTO 1470
820 GOSUB 5970
830 CODE$="999490":GOSUB 5820:FOR TIME=1 TO DELAY:NEXT TIME:GOSUB 6290
840 I1$(PL(U),2)=VIN$
850 CODE$="":IF D(PL(U),2)=1 THEN CODE$=CODE$+"9890"
860 IF M(PL(U),2)=0 THEN CODE$=CODE$+"9390"
870 GOSUB 5820
880 GOTO 1470
890 IF A$<>"V" THEN 3030
900 IF CHN=2 THEN 2970
910 GOSUB 5970
920 CODE$="8890":GOSUB 5820:FOR TIME=1 TO DELAY:NEXT TIME:GOSUB 6290
930 D1$(PL(U),1)=VIN$
940 IF D(PL(U),1)=1 THEN 1470
950 IF M(PL(U),1)=0 THEN CODE$="8990" ELSE CODE$="898490"
960 GOSUB 5820:GOTO 1470
970 GOSUB 5970
980 CODE$="9890":GOSUB 5820:FOR TIME=1 TO DELAY:NEXT TIME:GOSUB 6290
990 D1$(PL(U),2)=VIN$
000 IF D(PL(U),2)=1 THEN 1470
010 IF M(PL(U),2)=0 THEN CODE$="9990" ELSE CODE$="999490"
020 GOSUB 5820:GOTO 1470
030 PRINT BELL$;:GOTO 1800
040 CODE$=HEX$(ABS(INT(VAL(VOLT$(PL(U),CHN))/CNST)-2047))
050 F$="000":IF LEN(CODE$)=3 THEN 3080
060 X$=MID$(F$,1,3-LEN(CODE$))+CODE$
070 CODE$=X$
080 GOSUB 5970:GOSUB 6110
090 GOTO 1470
```

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DIGITAL PROGRAMMING FOR PI-SERIES PLUG-IN INSTRUMENTS

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DIGITAL PROGRAMMING
FOR
PI-SERIES
PLUG-IN INSTRUMENTS

INTRODUCTION

Programmable plug-in instruments give the instrumentation engineer much greater flexibility -- and often, considerable savings in hardware costs -- by permitting the system program to control many parameters of signal sources and power supplies.

A growing number of Pulse Instruments Company plug-in modules, installed in Tektronix TM-500 Series Power Modules, are programmable. Using these building blocks, the user can easily configure a versatile custom test system employing a relatively small number of off-the-shelf plug-in units, plus PI-910 plug-in breadboard modules.

The following pages offer information on available hardware configurations, and information useful in preparing interface hardware and operating software for digital programming.

CONFIGURATIONS FOR DIGITAL PROGRAMMING

The following conditions must be met in order to use digital programming with PI-Series plug-in instruments:

a. The PI-Series instruments must contain the -002 option (digital programming).

b. The PI-Series instruments must be installed in a Tektronix TM-500 Series Power Module (mainframe) containing the Tektronix Option 02.

c. The mainframe must have a backplane modified by Pulse Instruments Company (for example, MOD-DP).

The TM-500 Series Power Module (Mainframe)

These Tektronix products are assemblies comprising a frame with a backplane to accommodate up to six plug-in instruments. For example, TM-501 accepts only one plug-in, while TM-506 accepts up to six plug-in units. The assembly also contains a power supply furnishing ac and unregulated dc power, at different voltages, to be regulated as required by the individual plug-in units.

The TM-506 mainframe is available for rack mounting.

The Tektronix Option 02 provides input/output connectors on a rear panel, including BNC connectors, a 50-pin D-type connector, and a wiring kit for inter-plug-in connections.

Pulse Instrument Co. wires the mainframe assembly to accommodate groups of PI-Series instruments. There are presently five standard wiring configurations (refer to Table 1).

Note that, when the mainframe has been wired to accommodate digital programming, any affected plug-in slot is keyed to accept only compatible plug-in instruments. However, plug-in instruments equipped with digital programming and/or rear-access options may be used in standard mainframes (not modified by Pulse Instruments Co. or the user) as standard plug-in units.

Mainframe Wiring for Digital Programming

The TM-500 Series Power Module (mainframe), including Option 02, must be specially wired for the instruments it is to contain.

Table 1 gives the five standard modifications, along with a listing of PI-Series plug-in instruments compatible with that wiring modification, and connector information for each wiring modification.

Note that MOD-200 accommodates the PI-100A Clock Generator (not digitally programmable), and the PI-210 Word Generator. MOD-200 wiring is for high-speed signals, connecting clock signals from the PI-100A Clock Generator to PI-210 plug-ins. MOD-200 may be combined with any wiring modification for digital programming (for example, MOD-200/454A) so that the modified slot can accept a PI-210, or a PI-454A or other digitally programmable plug-in. Note that the slot wired for the PI-100A accepts only a PI-100A plug-in.

A PI-modified mainframe is designated to indicate the custom-wired plug-in slots. For example, MOD-451A-16 indicates that slots 1 through 6 have been wired for MOD-451A. PI-wired slots are keyed to accept only compatible Pulse Instruments Co. plug-in units.

Table 2 lists wiring connections for digital programming, excluding rear input/output connections.

Users who have attempted to perform these wiring modifications have, generally, reported having considerable trouble in their attempts. Therefore, Pulse Instruments Co. recommends either that compatible mainframes be shipped to Pulse Instruments Co. for modification, or that the complete modified mainframe be purchased directly from Pulse Instruments.

Table 1. Mainframe Modifications and Plug-in Compatibility (TM-506 only)

		Mainframe Modification				
		MOD-200[7]	MO -451	MOD-451A	MOD-454	MOD-454A MOD-DP[1]
PI-Series Type	PI-100A[6]	Compatible				
	PI-110		Compatible	Compatible	Compatible	Compatible
	PI-210	Compatible	Compatible[2]	Compatible[2]	Compatible[2]	Compatible
	PI-451		Compatible	Compatible	Compatible[3]	Compatible[3]
	PI-451A		Compatible[4]	Compatible[4]	Compatible	Compatible
	PI-454		Compatible[4]	Compatible[4]	Compatible	Compatible
	PI-702		Compatible[5]	Compatible	Compatible[5]	Compatible
	PI-720		Compatible[5]	Compatible	Compatible[5]	Compatible
No. of rear input BNC connectors		None	6	6	6	6
No. of rear output BNC connectors		None	6	12	6	12
No. of 50-pin digital programming input connectors		None	1	1	1	1
No. of 25-pin monitor output connectors		None	None	1	None	1
Input/output connections to rear BNC connectors		None	Twisted prs $Z_0 \cong 100\Omega$	Twisted prs $Z_0 \cong 100\Omega$	RG-178B $Z_0 = 50\Omega$	RG-178B $Z_0 = 50\Omega$

[1] MOD-DP is identical to MOD-454A and will replace MOD-451, MOD-451A, MOD-454, and 454A after Jan. 15, 1982.

[2] MOD-200 required.

[3] Higher-capacitance 50-ohm cable will result in increased output rise and fall times at rear connector.

[4] Impedance mismatch caused by using twisted pair instead of 50-ohm cable may result in overshoot or ringing at rear connector.

[5] Only one rear output is available.

[6] Slot for PI-100A will not accommodate any other PI-Series plug-in

[7] Any PI-Series plug-in will fit in MOD-200 mainframe if rear access is not required (excludes digital programming).

Table 2. Mainframe Wiring for Digital Programming

Signal	J7: 50-pin Connector	Plug-in Position	Plug-in Connector Pin	LS TTL Unit Loads[1]
D1	1	All	20B	6
D2	34	All	22B	6
D3	2	All	25B	6
D4	35	All	24B	6
D5	3	All	21B	6
D6	36	All	19B	6
D7	4	All	17B	6
D8	37	All	18B	6
D9	5	All	23B	6
D10	38	All	16B	6
D11	6	All	15B	6
D12	39	All	14B	6
$\overline{PS1}$	9	1	25A	1
$\overline{PS2}$	10	2	25A	1
$\overline{PS3}$	11	3	25A	1
$\overline{PS4}$	12	4	25A	1
$\overline{PS5}$	13	5	25A	1
$\overline{PS6}$	14	6	25A	1
$\overline{MS}$	7	All	28A	6
CS	41	All	28B	6
DS	8/25[2]	All	26B/27B	6

Notes:

1. All lines except DS are open and user must provide pull-up or pull-down resistors or circuits external to the mainframe. Do not operate the programmable mainframe with the digital programming interface cable disconnected at either end.

2. Use twisted-pair within mainframe and in digital programming interface cable (such as P/N 88000020).

SYSTEM ORGANIZATION

Figure 1 shows the general organization of hardware in a typical digital programming system. The illustration shows a total of 48 plug-in instruments, installed in eight TM-506-02 mainframes.

Listener-only, and Talker/Listener, plug-ins may be mixed in a mainframe without restriction.

The PI Bus (refer to Digital Programming Interface) is connected in common to all mainframes (except for mainframe select lines, individual for each mainframe).

The PI Bus must be interfaced to the controlling system's Instrument Bus through a suitable PI Bus Interface. This interface must translate controller-generated control signals and commands into the language of the PI Bus, and convert plug-in-generated handshaking and status signals into the language of the Instrument Bus.

The PI-952 Instrument Coupler interfaces the PI Bus with the standard IEEE-488 Instrument Bus, working with up to 48 plug-in instruments (eight mainframes). Refer to PI-952A Instrument Coupler for a description of this product.

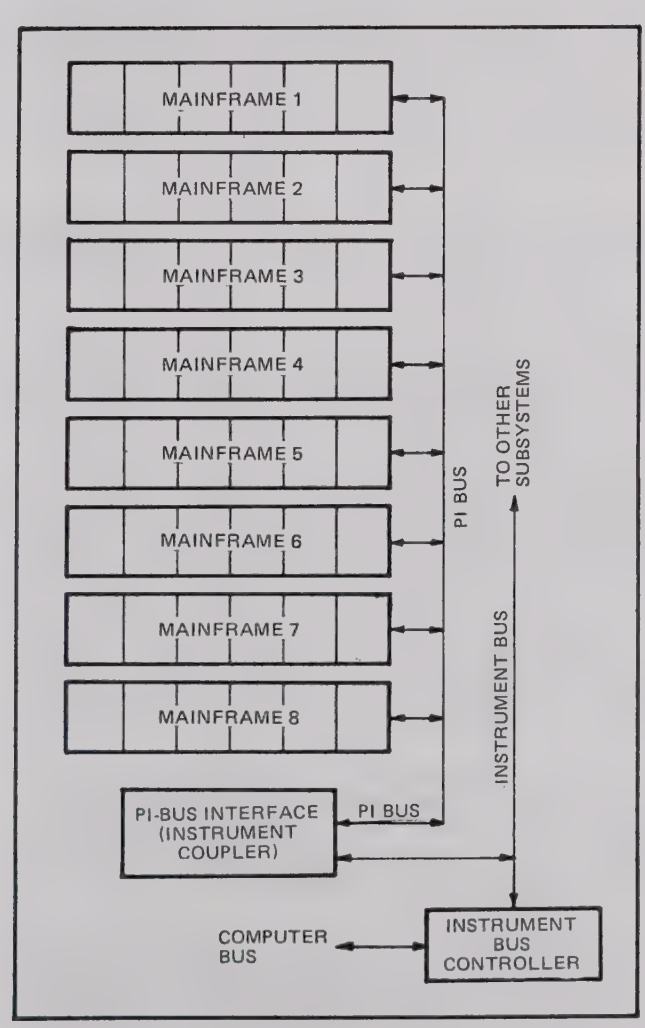


Figure 1. Typical System Organization

DIGITAL PROGRAMMING INTERFACE (PI BUS)

In order to digitally program a PI-Series instrument, the instrument must incorporate Option 002, and the mainframe backplane must be wired in accordance with instructions outlined in this manual (refer to Mainframe Wiring for Digital Programming).

Option 002 provides control logic and storage registers within the plug-in instrument which interface with the custom wiring in the mainframe. This wiring provides 21 lines connected from the backplane to a 50-pin D-type connector at the rear of the mainframe. The 21 lines have the following functions:

a. Data, or data and control (D1 through D12). Each of these 12 lines is wired, in daisy-chain fashion, to the connector for each plug-in unit. The nature of information on these lines depends on which of two possible modes of data transfer is required by the selected plug-in unit.

b. Mainframe Select ($\overline{MS}$). This line is used to select the specific mainframe, among others, that is to receive programmed information. That is, where more than one mainframe is used, each mainframe is selected by asserting its unique $\overline{MS}$ line.

c. Plug-in Select ($\overline{PS1}$ through $\overline{PS6}$). Each of these six lines is wired to a single plug-in connector, and is asserted to select the related plug-in for programmed control.

d. Channel Select (CS). This line is wired in common to all plug-in connectors, and is used to select either of two states of a selected parameter (for example; high level, or low level), or either of two parameters (for example; Channel A or Channel B).

e. Data Strobe (DS). This line, wired in common to all plug-in connectors, receives a programmed pulse which transfers the information on lines D1 through D12 into the programming data register of the selected plug-in unit. Transfer occurs at the rising transition (leading edge) of the DS pulse.

Once the mainframe, plug-in, and channel have been selected, lines $\overline{MS}$, $\overline{PS1}$-$\overline{PS6}$, and CS must remain at the select levels for as long as data is to be transferred to or from the selected plug-in instrument (or for CS, the selected level or channel).

No special enabling sequence is required when communicating with the instrument. The Data Strobe, however, should not rise until data has been on the bus for at least 14 microseconds, and must persist for at least 5 microseconds. Data may be taken off the bus 1 microsecond after the strobe has risen.

DATA TRANSFER MODES

There are two possible modes of transfer into a PI-Series instrument. The transfer mode to be used is determined entirely by logic requirements of the instrument.

Mode A may be used exclusively for plug-in instruments which act as listeners only. Mode A transfers all data (12 parallel bits) in a single transfer.

Mode B may be used with certain listener-only instruments, and must be used with PI-Series instruments which act as both talker and listener. Mode B transfers data byte-serially: That is, data is transferred in a succession of 8-bit bytes, with the four remaining data lines used for interface handshaking or other control functions.

The following paragraphs describe both transfer modes.

12-bit Parallel Transfer (Mode A).

In a Mode A transfer, data is presented to the plug-in instrument in 12 parallel bits. These bits may comprise three BCD digits, with bit D1 the most-significant bit. Or, bit D1 may specify the polarity of a programmed level, with bits D2 through D12 a binary number determining the level to a resolution of 11 bits (one part in 2048). The nature of the data is determined by requirements of the selected plug-in instrument.

Figure 2 shows the general timing required to perform a select-and-transfer cycle in a Mode A transfer. First the mainframe is selected ($\overline{MS}$), then the plug-in is selected ($\overline{PS}$), then the channel (CS). Data is then presented on the PI Bus and transferred to the instrument by the Data Strobe (DS) pulse.

Data may be encoded in either of two ways, depending on requirements of the selected plug-in instrument. The code may be:

- The complement of the 9's complement (used, for example, in the PI-110-02 Clock Period Multiplier); or
- Complementary offset binary (used, for example, in the PI-451-002, PI-451A-002, PI-454-002, and PI-702-002).

The following paragraphs describe each of these codes, giving examples of their derivation and application.

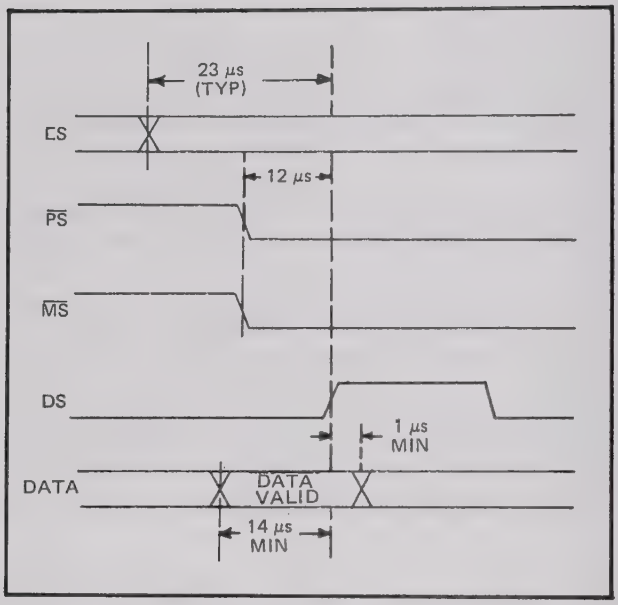


Figure 2. Typical Timing for a 12-bit Parallel Data Transfer

Complement of the 9's Complement. The following table shows how this code is related to BCD values. For example, the 3-digit BCD number 786_{10} would be encoded as follows:

Example

BCD 0111 1000 0110

Complement of 9's Complement . . 0010 0001 0011

n_{10}	$\overline{8}$	$\overline{4}$	$\overline{2}$	$\overline{1}$
0	1	0	0	1
1	1	0	0	0
2	0	1	1	1
3	0	1	1	0
4	0	1	0	1
5	0	1	0	0
6	0	0	1	1
7	0	0	1	0
8	0	0	0	1
9	0	0	0	0

Complementary Offset Binary. This coding is best illustrated by an example. Table 3 is a typical truth table for the PI-451-002. Note that bit D1 specifies polarity, and bits D2 through D12 specify voltages in binary-weighted increments.

Table 3. Typical Truth Table, Complementary Offset Binary Code

D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	Output
±	12.5V	6.25V	3.125V	1.563V	.7813V	.3906V	.1953V	.09766V	.0488V	.0244V	.0122V	Level
0	0	0	0	0	0	0	0	0	0	0	0	24.9875V
0	0	0	0	0	0	0	0	0	1	1	1	24.9021V
0	0	0	0	0	1	0	1	0	0	0	1	23.9995V
0	0	0	0	0	1	0	1	1	0	0	1	23.9018V
0	0	1	1	1	1	1	1	1	1	1	1	12.50V
0	1	0	0	1	1	0	0	1	0	1	1	10.0097V
0	1	0	1	1	1	1	1	1	1	1	1	6.25V
0	1	1	1	0	1	1	1	1	1	1	1	1.563V
0	1	1	1	1	0	1	0	1	1	0	1	1.001V
0	1	1	1	1	1	0	1	1	1	1	1	0.3906V
0	1	1	1	1	1	1	1	1	1	1	0	0.0122V
0	1	1	1	1	1	1	1	1	1	1	1	0.00V
1	0	0	0	0	0	0	0	0	0	0	0	-0.0122V
1	0	0	0	0	0	0	1	1	1	1	1	-0.3906V
1	0	0	0	0	1	0	1	0	0	0	1	-1.001V
1	0	0	0	0	1	1	1	1	1	1	1	-1.563V
1	0	0	1	1	1	1	1	1	1	1	1	-6.25V
1	0	1	1	0	0	1	1	0	0	1	1	-10.0097V
1	0	1	1	1	1	1	1	1	1	1	1	-12.5V
1	1	1	1	1	0	1	0	1	1	0	1	-23.9995V
1	1	1	1	1	1	1	1	1	1	1	1	25.00V

With resolution of 11 bits (1/2048), the nominal maximum voltage of 25V (actually 24.98779V) may be resolved to 25/2048, or 0.0122V, the value of bit D12. The digital code corresponding to any positive voltage between zero and the maximum voltage is found by adding together bit weights whose sum is the required voltage. For example:

Encode the voltage +10.0097V, adding together:

6.25	(D3)
3.125	(D4)
0.3906	(D7)
0.1953	(D8)
0.0488	(D10)
10.0097	

The required code is obtained by setting each of the bits making up the sum (D3, D4, D7, D8, and D10) to a logic "0", and setting all other bits to "1".

In the example, then, the voltage +10.0097 is encoded as:

W = 010011001011

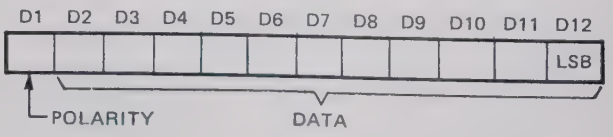
A negative number may be expressed as $\overline{W}$-1, where W is the code for the corresponding negative number. For example:

If W = +10.0097 = 010011001011, then

$\overline{W}$-1 = -10.0097 = 101100110100-000000000001 = 101100110011

Example of Mode A Data Transfer (PI-451-002). The PI-451-002 Programmable MOS/CCD Driver is a listener-only device permitting the programmer to select specified high and low pulse levels, either positive or negative.

Data for each level is presented to the instrument in a single 12-bit parallel transfer. Bit D1 defines the polarity of the voltage defined by bits D2 through D12. Data values are coded in complementary offset binary. Contents of the 12-bit transfer are as follows:



The CS line is made high to permit transfer of the high-level value, and then the strobe transfers that value into the instrument. The CS line is then made low to permit transfer of the low-level value, and the strobe transfers that value. High- and low-level data may be transferred in any order.

Byte-Serial Transfer (Mode B).

In Mode B, data is transferred, in either direction, in a succession of 8-bit bytes, or 4-bit "nibbles". Lines D5 through D12 are always used for data bits. Lines D1 through D4 may also be used for interface handshaking. The data transfer format and sequence are determined by requirements of the selected plug-in instrument.

Mainframe, plug-in, and channel select lines ($\overline{MS}$, $\overline{PS1}$-$\overline{PS6}$, and CS) are used exactly as in Mode A transfer.

Mode B may be used to control listener-only instruments, and must be used for talker-only and talker/listener instruments.

For specific formats and sequences, refer to documents for specific PI-Series instruments.

Following is an example of Mode B data transfer across the PI Bus.

Example: Mode B Data Transfer (PI-720). The PI-720 Dual-Channel Bipolar Power Supply is a typical listener/talker instrument working through the PI Bus interface in Mode B; that is, in an 8-bit byte-serial transfer. Information is transferred into the PI-720 in four 4-bit nibbles, with the 12 PI Bus data lines working as follows:

D1-D4 -- Interface handshake signals used for each byte transfer.

D5-D8 -- Address, directing each nibble to four DAC latches or to control logic.

D9-D12 - Either one of three data nibbles, or Range/Mode selection bits.

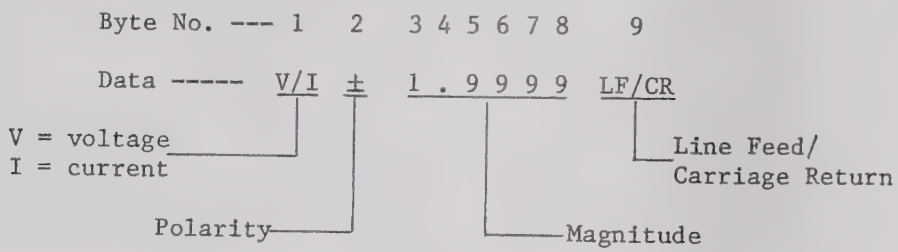
Data bytes having a value greater than hex 3F, or less than hex 80, are invalid and ignored by the PI-720. Bytes greater than hex 80 (bit 5 is set) are treated as instrument commands. (Refer to the PI-720 Instruction Manual for command information).

Figure 3 illustrates the nature and contents of information transferred into the PI-720. Figure 4 shows timing of data and handshake signals at the PI Bus interface.

To read data from the PI-720, the controller first sets bit D1 to put the instrument in the talker mode. The PI-720 then presents to the interface (on lines D5 through D12) the first of a string of nine ASCII-coded data bytes.

The PI-720 drops EDR (External Data Ready), and the controller responds by dropping INHIBIT to read the byte on the PI Bus. After INHIBIT rises, the PI-720 puts the next byte on the bus. This cycle is repeated until all nine bytes have been read.

The nine bytes present information as follows:



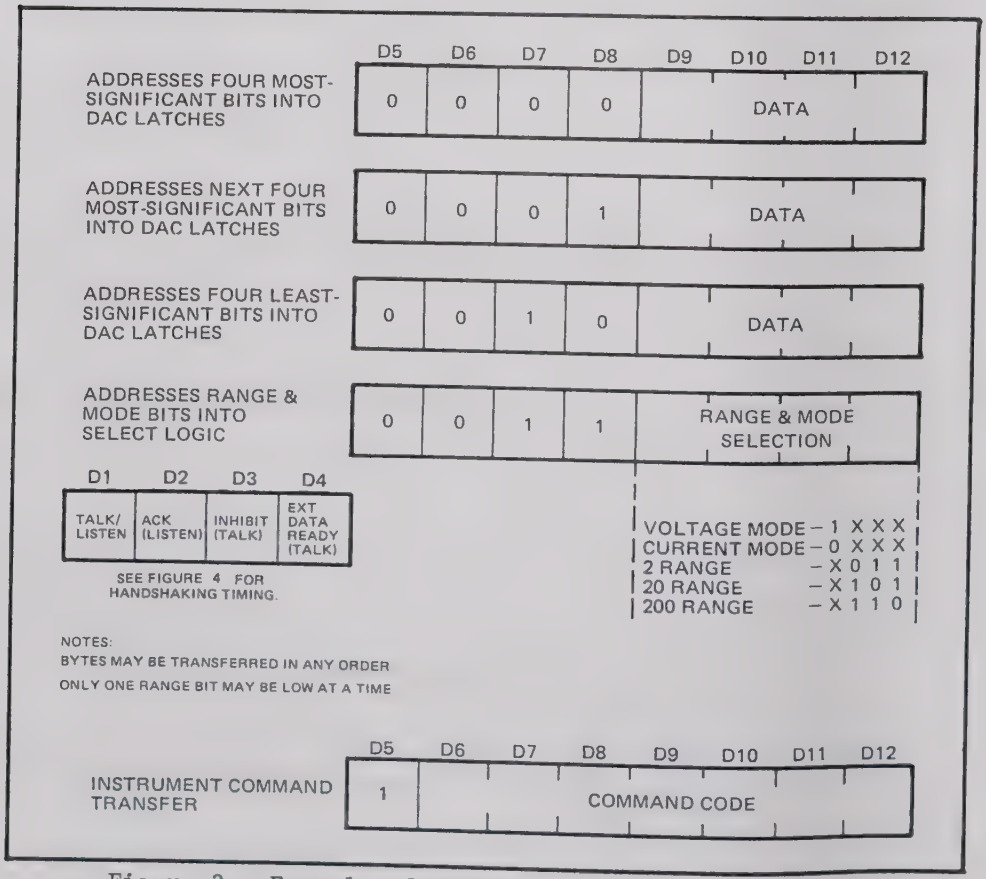

D5 D6 D7 D8 D9 D10 D11 D12
ADDRESSES FOUR MOST-SIGNIFICANT BITS INTO DAC LATCHES
0 0 0 0 DATA
ADDRESSES NEXT FOUR MOST-SIGNIFICANT BITS INTO DAC LATCHES
0 0 0 1 DATA
ADDRESSES FOUR LEAST-SIGNIFICANT BITS INTO DAC LATCHES
0 0 1 0 DATA
ADDRESSES RANGE & MODE BITS INTO SELECT LOGIC
0 0 1 1 RANGE & MODE SELECTION
D1 D2 D3 D4
TALK/ LISTEN
ACK (LISTEN)
INHIBIT (TALK)
EXT DATA READY (TALK)
SEE FIGURE 4 FOR HANDSHAKING TIMING.
VOLTAGE MODE – 1 X X X
CURRENT MODE – 0 X X X
2 RANGE – X 0 1 1
20 RANGE – X 1 0 1
200 RANGE – X 1 1 0
NOTES:
BYTES MAY BE TRANSFERRED IN ANY ORDER
ONLY ONE RANGE BIT MAY BE LOW AT A TIME
D5 D6 D7 D8 D9 D10 D11 D12
INSTRUMENT COMMAND TRANSFER
1 COMMAND CODE

Figure 3. Example of Mode B Data Transfer (PI-720)

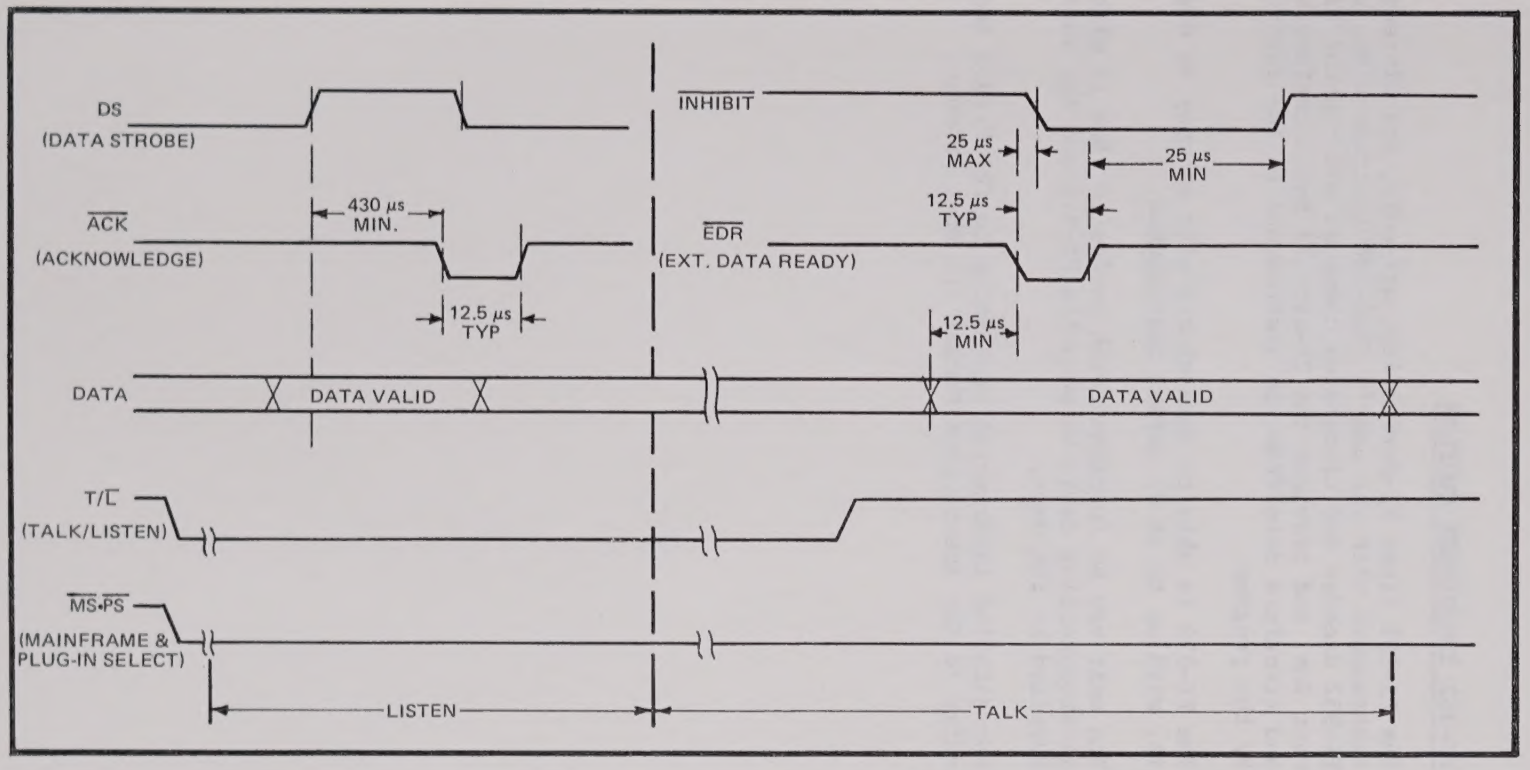


Figure 4. Typical Timing for Byte-Serial Data Transfer

PI-952 INSTRUMENT COUPLER

The PI-952 links PI-Series listener-only, and listener/talker, plug-in instruments with the user's IEEE-488 Instrument Bus controller. The PI-952 decodes and translates commands and control signals on the Instrument Bus, and provides the 21-line PI Bus interface with the instruments; and transfers data from the instruments to the Instrument Bus to be read by the program.

The PI-952 is able to communicate with as many as eight mainframes; that is, with up to 48 PI-Series instruments.

The unit may be furnished with cables to link it with the PI Bus. The interconnecting cable between the PI-952 and the Instrument Bus must be supplied by the user.

For detailed information pertaining to the PI-952 Instrument Coupler, refer to the Instruction Manual for that product.

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